QUALITY ISSUES IN VACUUM

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Abstract
This paper takes a brief and somewhat subjective look at some of the issues which arise when one begins to think about the concept of "Quality" as applied particularly to vacuum system specification.

1. WHAT IS "QUALITY"?

It is perhaps unfortunate that when the word "quality" is used in relation to some object, component, system or whatever, it is often assumed to mean that it is of the highest possible standard or that it is in some way state-of-the-art. The word therefore carries connotations of great care, superb workmanship and great expense. It is in some way used to convey a sense of "goodness".

However, to use the word in this way is misleading. A much more appropriate definition of quality is fitness for purpose. In other words, if a job is a quality job then it will fulfil what it is meant to fulfil but it will not exceed those requirements. The standard of the job will be sufficient and not excessively high.

Quality in the sense that is going to be assumed from now on means meeting the needs and expectations of the user, that is fitness for the purpose of the user. Difficulty arises in that users may not know what they actually require. A user will often tend to over-specify just to be safe, but is then unwilling to pay the necessary costs. It is therefore imperative that users' requirements are carefully checked by system designers.

2. QUALITY SYSTEMS

It is salutary to note that most organizations and commercial undertakings now work under so-called Quality Systems such as, for example, ISO 9001 but that in the main, these systems actually say nothing about quality in reference to standards of work *per se*. They are primarily documentation and tracing systems which will detail how a job has been handled, although, where appropriate, they will at some stage refer to the adherence of a job to its technical specification.

Quality systems are, as stated, primarily documentation systems and indeed usually involve a great deal of documentation. In the case of a manufacturing enterprise for example, all processes – handling, working, treatment, packing, etc. – from goods inward to dispatch are spelt out in detail and the appropriate tracing documentation and certification required at each stage laid down.

Such documentation systems have a great potential for becoming fossilized, but when used properly they provide the necessary information required to carry out audits of the process, to help the system to evolve by, for example, reducing costs without sacrificing standards, and to improve in some way the whole process.

3. VACUUM SYSTEM QUALITY

There are two main aspects to be borne in mind when thinking about the quality of a vacuum system, *viz*., system design and system performance.

3.1 Vacuum system design

To some extent this is the straightforward part of the process since most competently designed vacuum systems will be designed and built to well understood engineering standards. Factors such as size, shape, tolerances, stability, motions, heat dissipation, etc. can all be specified in detail. When the system is built, all of these can be accurately checked by standard techniques. It is sometimes the case that in vacuum systems for very particular purposes, the state of the art may not be good enough, but that is a different story.

3.2 Vacuum system performance

Specifying the performance of a vacuum system may also be thought at first to be straightforward, but in practice, this is not the case.

Firstly, it is important to note that the majority of users of vacuum systems are not really interested in vacuum at all. It is simply that they wish to work in a controlled atmosphere and that vacuum happens to be the easiest such controlled atmosphere to use. Examples of such uses are particle accelerators, where beam scattering should be minimized; metal refiners and semiconductor manufacturers where contamination of the product is an issue, etc.

4. SPECIFICATION OF A VACUUM SYSTEM

4.1 General

Fundamentally there are two different methods of specifying the performance of a vacuum system: specification by process and specification by performance. The former involves the designer, who in this case will probably either be the user or closely associated with the user, spelling out in detail every aspect of the vacuum system, confident that provided the manufacturer sticks to procedures, the desired result will be achieved. The latter approach simply states what the vacuum system will do and leaves the manufacturer to decide how to meet this performance, which will, of course, be checked.

4.2 Specification by process

This approach puts the responsibility for achieving the desired quality firmly on the system designer. This is fine so long as the system in fact meets its requirements, but gives rise to possible conflicts if the performance falls short of requirements. Has the manufacturer not adhered to procedures properly? Is the system under-pumped? The designer accepts the costs of the design process, so manufacturing costs should be less. However the purchaser must be prepared to supervise the manufacturing process closely and check frequently that everything is being done as required.

The designer will require an intimate knowledge and understanding of things like choice of materials, manufacturing techniques, cleaning processes, handling procedures, outgassing rates, pumping and gauging, etc.

Traditionally, accelerator builders have used this approach, but tend to muddy the waters slightly by also placing performance specifications on manufacturers.

Most of the risk here is borne by the designer/purchaser.

4.3 Specification by performance

Here, the user will specify the way in which the system is to perform with respect to important operational parameters which might include the required pressure, pump down times, residual gases, outgassing rates, etc., and may include the elimination of unwanted side effects such as particulate production and cross contamination.

The responsibilities for ensuring that the performance is achieved are here quite clear. They lie firmly with the manufacturer who will design the whole system mechanically, specify the pumping and gauging, etc. However the purchaser must be prepared to accept the costs of doing this and most manufacturers will also build in contingency costs for rectification work if the desired performance is not achieved.

A potential problem lies in how the performance is to be measured and this must be clearly understood before an order is placed. Performance testing is discussed in the next section.

This approach has traditionally been used by industrial purchasers, where in-house understanding of vacuum may be quite low. In practice a modified version of this approach will often be used with the purchaser carrying out part of the mechanical design work, leaving the manufacturer to do the vacuum bits.

Most of the risk here is borne by the manufacturer but the customer pays for this.

5. VACUUM SYSTEM PERFORMANCE AND ITS MEASUREMENT

There are many factors affecting vacuum system performance and its measurement, many of which have been dealt with in detail in this course so are simply listed here for completeness. The specifier, the designer and the purchaser's inspector will all require a knowledge of these if the finished system is to be of suitable quality. The limitations apply equally to whichever approach to specification as discussed above is used: the approach simply determines who carries the responsibility.

Factors which affect performance

- Materials
  - Mechanical Properties
    - Changes induced by heat, vacuum, by what the system is used for
    - Techniques
  - Working, joining
  - Outgassing rates
    - What influences outgassing
    - How is it measured
    - Are "book" values to be trusted
- Cleaning
  - What is to be cleaned
  - How and why
- Handling

Factors which affect measurement

- Required pressure
  - Measurement
    - Gauge calibration and stability
  - Pumping speed and stability
  - Uncertainties in measurement
- Residual gases
  - RGA calibration and stability
  - Uncertainties in measurement

6. REAL-WORLD VACUUM GAUGING

It is useful to note that the measurement of pressure in a vacuum system is usually a key factor in any specification. It is therefore of vital importance to know to what extent measurements of pressure can be trusted. Much of the published values for gauge sensitivities, stabilities, etc., come, understandably, from standards laboratories where gauges are used in near ideal circumstances.

Things are quite different in the real world of vacuum pressure measurements and not much is really known about the uncertainties inherent in such measurements. For example, there is usually little time allowed for taking such measurements, gauges are not allowed to outgas and stabilize and the system may not be in equilibrium. The personnel taking the measurements have limited vacuum knowledge and skills and are indeed often not really interested in the subject. They may have little experience on which to base an assessment of whether or not a reading is sensible. There is no appreciation of the effects of the state of the vacuum system (e.g. an external pump set) on measurements and how the past history of the system can affect readings.

The problem is compounded when it comes to using residual gas analyzers. Calibration of such instruments is in fact difficult and fundamentally not well defined. Judgement is required in interpreting the spectra. Most modern instruments are software driven and the real data is hidden from the user. The effects of interpretation algorithms are often not specified.

However, this is not to counsel that there is no point in doing such measurements, simply that a degree of caution needs to be applied in interpreting results

7. SUMMARY

This paper has discussed two basic approaches to the application of quality thinking to the specification of vacuum systems in which the specifier either accepts control of the manufacturing process and the risk involved or specifies what is required and passes the risk to the manufacturer but pays the price.

In each case, both specifier and manufacturer must clearly understand who is accepting the risk and where responsibility lies. They must also clearly understand from the start how the assessment of the completed system is to be achieved and the limitations of the processes involved.